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THE PHYSIOLOGICAL BASIS OF EDUCATIONAL THEORY.

BY S. DE BRATH,

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> "More and more, if it is to be truly successful, must education be based on our knowledge of cerebral function, and be moulded by the discoveries of experimental psychology. As yet it contemptuously ignores these. It often thwarts instead of guiding brain growth, checking by its interference the spontaneous process of natural evolution."—*Sir James Crichton Browne, M.D.*

(1.) NERVOUS OVERSTRAIN. Of all the progress whereon our century is wont to plume itself none is more prominently put forward than our improvements in sanitary methods. The discoveries of bacteriologists are applied almost as soon as made, and food, water, drainage, soil, and the conditions of physical life generally, are watched over by the legislature and considered by the individual with more attention than ever before.

But, while the corresponding decrease of zymotic disease has been most striking, this has been accompanied by an even greater increase in those ailments which are pre-eminently termed "nervous," and there is a body of evidence which points to the conclusion that these increasing ailments show varieties sufficiently pronounced to be made the basis of charges of degeneracy. Even Professor Max Nordau's hyperboles cannot invalidate the drift of the evidence he brings forward. We reprobate the jovial ways of our grandfathers, who not only lived to a good old age but continued hale and hearty till late in life, although they permitted themselves a freedom which we are unable to bear, and some of us even drag in hearsay biology, and charge upon heredity not only our nervous instability, but even the transmission of ailments from which our forbears did not suffer. But as they were not victims to nervous exhaustion it is at least open to question whether they transmitted it, and whether, in fact, the pleasant theory is true that the heredity which was made for us rather than the environment which we make for ourselves, is to blame for diminished vigour. For diminished vigour there certainly is. The jaded condition of large numbers of professional and business men, the constant need for rest and change of air and scene, are too common to need proof, and this is accompanied by a distinct diminution in massiveness. When, a short time since, the bones of some of those who fell at Waterloo were moved to a new resting-place, it was noted that nearly all were skeletons of men six feet high. The superiority of British to continental physique has now practically disappeared; and not only has the height and chest measurement of our recruits steadily fallen, but the general smallness of men and women in our towns is patent to any observer who remembers that a healthy Englishman should stand 5 ft. 10 in., weigh 12 stone, and measure 39 inches round the chest.

Among our educated classes it is a common complaint that sons and daughters have not the physique of their parents, that they suffer from neuralgia or anæmia, and need frequent medical advice. And this falling off is general among classes whose nourishment leaves nothing to be desired, and among quite young men. At the Conference held at Rugby, in December, 1896, the head master of one of our greatest public schools said that "the medical officer at Woolwich had stated that a considerable number of the cadets were not of good physique, were intellectually overworked, and were of anæmic appearance." Pale undersized boys and girls abound, wrinkled foreheads, headaches, constant "colds," tonsilar growths, nervous twitches, unsymmetrical development, and breakdowns in preparing for examinations, are so frequent as scarcely to meet the attention they deserve. Early decay of teeth is rather the rule than the exception, while medical testimony is abundant and singularly unanimous to the increase of impaired eyesight in children. Nor is the importance of these facts lessened because every large school has a number of boys who distinguish themselves in the cricket and football field, and whose fine development is constantly appealed to as a standing proof that all is well in the best of all possible schools in the leading country of the world. For along with these there is also a number, sometimes a very considerable number, of boys who take little share in the games except to stand about as onlookers at those contests wherein the honour of the school is upheld by picked teams of athletes. I know more than one public school where every boy must join in the games or show a medical certificate, but I know also at least one very large public school where the masters are satisfied if a good crowd of boys assemble to "show interest" in the form matches.

So grave has the evil become that special studies have been undertaken by medical men to determine the signs of nerve strain in children, and medical opinion now confirms the conclusions emphasized in 1877 by Herbert Spencer, that the mischief is largely due to bad methods of teaching, and to the system of cramming for examinations; which latter, perhaps from deference to the general attitude of schoolmasters in face of the problem, is usually taken for one of the inevitable evils of civilized life. But are these conditions unalterable? Is it the fact that modern life is necessarily productive of nerve strain and all its attendant evils, which are therefore unavoidably forced upon us; and that the tests which guard the professions from dangerous ignorance and from superficial knowledge more dangerous still, are unduly severe and involve unhealthy over-exertion to the average boy? Or, is it not rather that much of the "worry" and "rush" is due—apart from our forgetfulness of the lesson "not to be anxious for the morrow"— to want of method, to feverish endeavour to catch up lost time, to the need for acquiring knowledge at the very time that our duties call for its exercise; these causing that greater haste which is the proverbial synonym for less speed?

Would not methodical work from the early years enable the average boy of the professional classes to reach his standard without cram or overstrain, and thus fulfil that law of steady, natural, quiet growth, which is the first lesson to be learned of those lilies of the field, which we are enjoined to consider? For the answer we must go to the exact seat of the trouble, and use all the information with which a singularly able body of specialists has presented us. Laws of growth are not less binding because in man they enter into the field of consciousness, and the modern world is so complex that only by the concurrence of many special forms of knowledge can true progress be made in any one. It is for the teacher who would guide himself to the best practice of his own profession, to understand, as far as may be, the processes with which he has to deal; to know the results, to enter into the labours, and to use the conquests of the physiologist. These results tend more and more to show the nervous force as the proximate cause of all bodily change and development, including those phenomena of thought and emotion which are the special subject-matter of psychology.

It is to the increased supply of this nervous force, that attention should be directed in the case of children in whom a small power of resistance to slight causes shows its deficiency, rather than to the removal of the external causes, which are but the occasion for ailments.

It is in the habitual economy of this force, by wise habits of life, that the best and highest development of the organism is to be looked for, and by such economy and judicious use alone can a high standard be reached without overstrain.

This nervous force is the power on whose right direction depends, first, the physical and mental symmetry of the organism, and afterwards its healthy reactions in contact with the manifold experiences of life, which are called skill knowledge and directive ability, and before we can undertake to direct it at the present time, when failures are so common, it is essential that accurate knowledge should supplement the personal experience which must ever be the chief factor in successful teaching.

(2.) INNERVATION. The examination of an egg which has been incubated two or three days, will show in the yolk a few crawling veins of bright red colour and a small groove of membrane. The veins speedily become a branching net, and the open groove gradually changes to a closed cylinder, the future cerebro-spinal canal, by its margins growing up and meeting above it, and thenceforward it becomes the axis round which the hidden creative power develops the body which is to be. Not the bony framework, nor the circulatory system first appears, but the substance of the organism, and the instrument of the force which moulds it. The first manifestation of its life is a central nerve, which is the instrument of all further growth, and remains always the centre of its life.

In the human subject this central seat of life (the cerebro-spinal axis) is protected in a way which seems to emphasize its importance. Lying in the skull and in the middle of the vertebræ, it is almost entirely surrounded by bone. From the brain, consisting of two convoluted hemispheres of white and grey nerve stuff, descends through a tube formed by the vertebræ, a cord of the same substance, about as thick as the little finger. From the central cord spring (Fig. 1) bundles (fascicles) of nerves in thirty pairs, which arise each from two roots at the same level in the spinal column, one root being in the front and the other at the back of the cord, each pair being bound into one nerve trunk by a white fibrous sheath. These fascicles, which are about the thickness of stout string, are constructed on the same model as the central cord, and are interlaced in groups (plexuses), the first four of the neck forming the cervical group; the last four and the greater part of the first dorsal joining to make the brachial group for the supply of the upper limbs; and the lumbar and four upper sacral nerves forming the groups principally distributed to the lower limbs. Besides being thus intimately connected into groups, the nerve fibres are at certain places gathered into knots (ganglia), some of whose functions will appear later. There are also several pairs of cranial nerves which take their rise at the top of the spinal column and ramify to and from the different parts of the head and the organs contained in it. The whole of the body is therefore in close communication with the brain either directly or through the spinal cord.

Injury to different parts of this nervous system produce very different results. Should the whole cord be cut right across as may occur in certain bullet wounds, all feeling and power of motion ceases in the limbs supplied by that part of the cord severed from communication with the brain. But this can be known only from the patient himself, for if the limbs be pricked or otherwise irritated, movements occur, these being due to the ganglia above mentioned, which seem to act as a kind of small local brain, producing movements of which the sufferer is unconscious. This is called reflex action, and this reflex or ganglionic action in the functions of the heart, lungs, and digestive organs plays an even greater part in the human economy than the conscious life of the central brain.

Should the injury be to the anterior roots of a pair of nerves going to one of the limbs, these anterior roots being divided while the posterior roots are uninjured, though the parts supplied by the nerve will be limp and paralysed in respect of motion, they will retain their full sensibility. If, on the contrary, the injury has been to the posterior root, the power of motion will remain, but the parts may be pierced, burned, or cut without causing pain. It is not unusual to divide the nerve-branch to the posterior root for certain foot diseases of the horse with the object of leaving the animal the painless use of a hopelessly diseased limb. From many similar facts it appears that the part of each fascicle of nerves which runs into the spinal cord by the anterior roots carries the impulses of motion, and the part which enters by the posterior roots those of sensation, which is expressed by saying that the one set of fibres is motor and the other set sensory.

As the human body consists of two halves very nearly symmetrical on either side of the spinal column, it is clear that if each side of the brain were connected exclusively to its own side of the body and limbs, the right and left halves of the organism would be to a very considerable degree independent of one another. Accordingly, the main trunks of the nerves which carry sensation from the right side of the body cross over (decussate) to the left side of the spinal cord and *vice-versâ*; while the fascicles of nerves, which carry motor impulses similarly, cross over just below the base of the brain. Each side of the body is, therefore, chiefly (though not entirely) connected with the opposite side of the brain, both as regards its sensory and motor fibres; but the sensory fibres cross over all along the spinal cord, while the motor fibres cross just below the brain. There is also in the hind brain a tract whose special function is to unify the motor impulses, and probably to a certain extent the sensory impressions also.

In appearance all nerves are alike, but physiologists place them in two great classes, according to their uses, and distinguish the members of each group by minor differences of function. These functions are expressed in tabular form below:—

Class I.—SENSORY. Separated into Groups.

- (*a*). Nerves of common sensation, or touch.
- (*b*). Nerves of special sense, smell, sight, hearing.
- (*c*). Nerves which minister to reflex action, which is so closely bound up with sensation that these are called excito-motor nerves.

Bound up for the most part with the same nerve trunks are:—

Class II.—MOTOR. Separated into Groups.

- (*a*). Nerves which move voluntary (striated) muscle.
- (*b*). Nerves which move involuntary (non-striated) muscle, giving rise to circulatory, digestive and other movements not under control of the will.
- (*c*). Nerves which stimulate secreting glands.
- (*d*). Nerves which minister in some special way to the nutrition of a part, injury to them resulting in atrophy of that part. (Trophic nerves).
- (*e*). Nerves which check the action of others for a time, by which we are enabled to "keep still," or to perform rhythmic motions. (Inhibitory).
- (*f*). Nerves which dilate the blood-vessels of particular parts. (Vaso-motor).

There are, in fact, two great sets of nervous conductors symmetrically arranged all over the body—the first (sensory) leading from the outer surfaces and from the organs towards the brain; and the other (motor) leading outwards from the brain to the muscles and the organs, the former being the mechanism of sensation, and the latter of motion voluntary

or involuntary. All movement, conscious or unconscious, is preceded by a nervous impulse, and as functional movement is continuous, the nervous flow must be continuous also—in short, all functions of whatever kind are dependent on these impulses which stimulate activity, and are conveyed by the continuous conductor which places all parts of the organism in connection with the great central telegraph office, at whose arrangements we shall now take a superficial glance.

(3.) THE MECHANISM OF THE BRAIN. Within the last few years a great light has been thrown on the machinery of sensation, thought and action by the researches of physiologists, who have dissected the brain into successive thin slices from top to base and from back to front, and photographing each of these hundreds of slices under the microscope, have built up maps of the brain, which enable its general structures to be studied from the point where they take their rise to that where they terminate. The fascicles of sensory and motor nerves which are gathered into each side of the spinal cord, mostly pass each into one of two distinct regions at the base of the brain, the sensory nerves into one distinct mass of nerve substance, and the motor nerves into another equally distinct but dissimilar mass, called from its curiously-striped appearance the corpus striatum.

To the former converge also the nerves of smell and taste (practically one), of sight and hearing; and the optic nerve being the most conspicuous of these, the mass in question early received the name of the optic lobe (thalamus).

In this mass of nerve substance there are four separate nerve centres, corresponding to the sense of touch and to the special senses above named; and that the exercise of these senses depends on the centres in question, quite as much as on the eye or ear, is proved by such cases as that quoted from Dr. Hunter by Prof. Luys, in which there was successive loss of smell, sight, sensation and hearing; the autopsy revealing the traces of progressive consumptive disease affecting these nerve centres in this order, the organs of smell, sight, and hearing themselves being quite healthy. Prof. Luys thus sums up: "We may, therefore, legitimately conclude that the isolated ganglions of the optic lobe (thalamus) are so many independent departments for each kind of sensorial impressions, and that the destruction of each of them may lead to the disappearance or alteration of the function to which it is specially devoted."

From these centres large numbers of fibrils radiate towards the surface of the brain, the centre of sensation being connected with all parts of this surface, and the others more especially with certain parts of it.

This "surface" of the brain wherein these fibrils end, is of very peculiar construction. It is grey in colour, and forms a kind of rind or "cortex" to the inner white substance which composes the mass of the brain. The microscope shows that the greyness is due to millions of tiny nerve-cells more or less pyramidal in form, arranged radially from the centre of the brain, towards which their bases are turned. From each of these cells proceed very delicate tufts of sensitive protoplasm, and in these tufts originate nerve fibres, which pass through the cell and form delicate rootlet-like fringes on the other side, the whole being imbedded in a matrix of white nerve substance.

The fibres from the centres of sensation in the optic lobe pass towards these cells and among them they are lost. Here we touch the profoundest mystery of physical life, the transformation of an external effect into consciousness. Here, among these tiny rootlets ends the whole elaborate mechanism of innervation which converges towards the brain, and here for the present is the limit of our knowledge.

In this cortex there are many convolutions, and examination of the brains of animals shows that there is a close connection between the number and complexity of the convolutions and the intelligence of their possessor. The human brain, though not differing in general structural plan from that of the highest brutes, is so much more highly developed and convoluted as to stand in a class quite by itself. But whether human or anthropoid it has long been known that certain convolutions (portions of the cortex) have to do with the motion of particular muscles. Dr. Bartholow, professor in the medical college of Ohio, found, with a patient suffering from severe injuries to the skull which exposed the brain, that slight electrification of particular portions of the cortex caused motion of particular muscles, such as those of the eyes, tongue, neck, fingers, arms, legs, &c. Many such experiments have demonstrated that particular tracts have an intimate connection with particular sets of muscles, these tracts or convolutions being known as psycho-motor centres, and it is highly probable that each muscle in the body has its own centre in the brain and conducting fibrils.

So far the cortex. But just as it was necessary for the due co-ordination of the right and left halves of the body that each should be connected with the left and right halves of the brain, so must the opposite sides of the brain be connected if co-ordination is to be complete. There are, in fact, in addition to the sensory fibres proceeding from the optic thalamus to the cortex, numbers of other white fibres which cross from right to left and connect similar psycho-motor centres and other homologous regions of the two lobes of the brain; so that an impression produced by the nerve current in one group of cells is communicated to all those with which it is as it were in telephonic communication. These transverse fibres complete the system of sensory nerves which pass inwards from the skin and end in the million-celled organ which conceals the instantaneous change from the physical nerve-current (which is not sensation till it reaches the cortex) to psychic consciousness. This is the flash of perception which continually repeated from moment to moment constitutes the stream of consciousness we are each of us aware of as our life in Time.

(4.) FUNCTIONS OF THIS MECHANISM. No sooner has the transformation from physical nerve current to psychic sensation taken place, than a reconversion into the physical begins. The perturbation of the nerve current was purely physical till it reached the surface of the brain and flashed into consciousness; this consciousness then originates a return current, or modifies the constant current, to produce a motor impulse.

Besides the set of fibres which radiate from the optic lobe upwards, and the cross fibres which connect similar regions on opposite sides of the head, the researches of physiologists have revealed a system of fibres, which, beginning in the surface of the brain, run downwards towards the great motor nerves and end in the muscles. These fibres converge in the first place to the motor centres in the corpus striatum, which, by similar experiment and reasoning to that which determines the optic lobe to be a meeting-place for ascending (sensory) impressions, can be shown to be a meeting-place for motor impulses descending from the cortex. Here also are four nervous centres each closely connected with the special activities of the organs of sense, and from these descend into the cord those fascicles of nerves which pass out from it by the anterior roots to convey stimulus to the muscles in which they terminate. We are now in a position to trace the course of an impression. A nerve current, probably continuous, flows along the whole course of the nerves, giving rise to a certain tension or “tone” in the whole body, and to those movements of its parts which are called growth and function, and the vigour of growth and function is determined by that of the current. Disturbances of this current by an exterior agent are conveyed by the main conductor (the “sensory” nerves of the spinal cord) to the appropriate centres in the optic lobe, and thence again to the cortex where special discharges of nervous power would seem to be set free by the actual disintegration of nervous substance, its amount and quality being probably dependent on the nature and previous arrangement of the cells and the kind of disturbance which reaches them. Here the physical touches the psychic so closely that it is mere speculative rashness to attempt to separate them. But it is clear that whatever changes may take place in the abyss of being which lies in that little span of grey matter there emerges thence a physical motor impulse, which finds its way through the return wire of the main conductor, and expends itself in muscular contraction and is dissipated according to the ordinary laws of energy, as heat and work. This, in roughest outline, is the path of changes which we call a sensation and its resulting voluntary act.

In the marvellous microcosmic world of human structure there are in addition hundreds of bypaths along which run conscious, semi-conscious and unconscious impulses; some for the many acts which, like swallowing, are partly under control, but many more for a vast number of nutritive, circulatory and secretory changes which are not; to say nothing of the underworld of mental change not yet come into manifestation, and of instinctive subliminal knowledge for the analysis of which there are as yet no data.

But the broad general truth is clear enough, and it throws a very distinct light on many processes both bodily and mental, especially on those which are especially associated with our conscious life. The impressions which fall upon our nerves produce many results, conscious and unconscious. Those which fall upon the nerves of special sense, such as our eyes and ears, are transmitted to the brain and there determine certain paths of nervous discharge some of which are the representation to consciousness of their causes. The voluntary redirection of this discharge along the same paths constitutes an act of memory, vivid in proportion as the original discharges are more or less exactly reproduced; and when these are sufficiently strong, the impression amounts to a visualization of objects which have been actually seen or whose component ideas have been seen or visualized on previous occasions. Association of idea, which plays so considerable a part in our mental processes, is the natural result of the allied sensations which accompanied the original impulse or one or other of its subsequent or similar repetitions, and it follows naturally, *cæteris paribus*, that the durability of impressions made on similar minds will be proportionate to the extent and variety of nervous action which those impressions set in motion. If this theory of memory be sound, no argument is needed to show how much more impressive must be the teaching which appeals to two or three senses, and, linked to the child’s own past experiences, becomes part of the fabric of his life, than that which appeals to the single sense of hearing by means of words. Apart from the fact that words are mere conventions of unmeaning sound to a child till it has built up a meaning for them out of the more or less distinct images of its experience, it is clear that no words can affect as large a tract, or produce impressions as vivid, and associations as numerous as the sense-perception of the things themselves. Thus it is that history teaching which is a mere rehearsal of names and dates, fades from the mind, while that which is based on a mind picture of a race by means of presentation of their dress, arms, tools, architecture, literature and social life remains; thus also actual experiment in chemistry or physics—the “heuristic” method which makes the learner discover for himself in logical order—leaves impressions which are too vivid to be obliterated, while the mere description of apparatus and experiments learned out of books vanish away. Mathematical verbal rules are clearly remembered only by children already predisposed to mathematical learning, but learned by concrete examples, by weighing, measuring, and by true geometry dealing with concrete and truly-drawn plans of certain shapes, it becomes fixed in the mind, which is thus trained to make each particular experience lead up to the generalization which it cannot forget if it would.

The physiological basis of habit is not less obvious. "Inter-communicating nerve paths are marked out in the brain,. . . .at every repetition of a movement or set of associated movements, the cells act more readily and with less effort of will, for the nerve paths become more clearly marked out, and impressions tend to slide more readily along them, until in time the movements or combined actions become almost unconscious or automatic. They have become habit, bad or good; they possess the body, which loses control over them. Transfer the picture to the intellectual sphere, and we see the same formation of mental habits as is found in the less mysterious muscular training."

Lastly, we may see here some light on the moral law, that it does not suffice to abstain from evil in act, but that all true repentance is a μετανοια, a turning of the desire by which internal energies are directed. For as surely as the voluntary calling up of the forbidden images in the mind stimulates the nerve flow, and directs it along channels which affect the whole system and lead to realization in act, so surely will that realization from time to time repeat the Fall, which immutably follows hard upon allowed Desire.

(To be continued.)

REASONS FOR STUDYING GEOLOGY.

By the Rev. H. H. Moore, M.A.,
Vicar of St. John's, Darwen.

What is Geology? Mistaken notions and prejudices about it.

Those who have tried to persuade others to take up the study of Geology, or who have had to do with arranging for public lectures on that subject, soon discover that it is not generally considered an attractive subject. Most people seem to regard it as a dull science, dealing only with dry bones and old shells, and they regard with mixed amusement and contempt the enthusiastic geologist tramping across the country, banging the rocks with his hammer, and filling his wallet full of stones and fossils. In fact, the common view of geology and geologists is pretty nearly that of the strong-minded and irascible hostess of the old hotel at St. Ronan's, in Scott's novel of that name, who expressed her contempt for the visitors at the "new hotel" by saying that "some rin up hill and down dale, knapping the chucky stanes wi' hammers, like sae mony road-makers run daft; they say it is to see how the world was made." The first thing to do, therefore, in trying to inoculate people with a proper appreciation of the delights of geology, is to disabuse their minds of the notion that it is "all fossils." Paleontology—that is, the study of the petrified remains of the vegetable and animal life of previous ages of the earth's history—is only *one* department of geology. It is an important one, it is true, for the fossils of certain plants and animals, being characteristic of certain strata, greatly assist the geologist in determining the ages, order, and character of the various strata, just as the architectural details of our cathedrals, abbeys, and churches enable us to determine the order of architecture and the age to which they should be assigned. It is as